

1 PIEZOELECTRIC ACTUATOR

2 *Background of the Invention*3 ^{Prior Art}
45 ~~The invention concerns a piezoelectric actuator, e.g., to actuate a mechanical~~
6 ~~component such as a valve or the like, according to the features—based on the~~
7 ~~general class~~ ~~of the primary claim.~~

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9 It is generally known that, by utilizing the "piezoelectric effect", a piezoelectric
10 element can be constructed out of a material having a suitable crystal structure.11 When an external electrical voltage is applied, a mechanical reaction of the
12 piezoelectric element takes place that, depending on the crystal structure and the
13 application regions of the electrical voltage, represents a push or pull in a
14 specifiable direction. The construction of this piezoelectric actuator can take
15 place here in a plurality of layers (multilayer actuators), and each of the
16 electrodes, via which the electrical voltage is applied, is arranged between the
17 layers. When the piezoelectric actuator is operated, care must be taken to ensure
18 that no disturbing crack formations develop in the ply structure by means of
19 mechanical stresses.20 *Summary of the Invention*21 ^{Advantages of the Invention}22
23 The piezoelectric actuator described initially, which can be used to actuate a
24 mechanical component, for example, is advantageously constructed with a
25 multilayer structure of piezoelectric plies and electrodes arranged between them.
26 With a lateral contacting of the electrodes in alternate directions, a neutral phase
27 forms in the region between two piezoelectric plies in each case. Since the
28 electrodes contacted on one side in each case are integrated in the ply structure
29 in the manner of a comb, the consecutive electrodes in the direction of the ply
30 build-up must be contacted on opposite sides, always in alternating fashion.

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1 As a rule, the electrodes contacted on one side can thereby not always be
2 extended completely to the opposite side, because voltage spark-overs could
3 otherwise lead to the destruction of the piezoelectric actuator. When the
4 piezoelectric actuator is operated, i.e., when a voltage is applied between the
5 opposing electrodes in the ply structure, different mechanical forces occur in the
6 region of the electrodes as well as in the non-contacted neutral phases, which
7 can lead to mechanical stresses and crack formations in the piezoelectric
8 actuator.

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10 In an advantageous exemplary embodiment according to the invention, one
11 electrode layer of the internal electrode that is contacted on one side is always
12 extended completely to the end of the other side at specified intervals, and the
13 external electrode lying on the other side in each case thereby bridges over this
14 layer to prevent a short circuit. The contacting in alternate directions is
15 constructed in such a fashion that two internal electrodes—that enclose an
16 internal electrode having the opposite polarity and contacted on the opposite
17 side—are contacted jointly on one side in each case. In alternating fashion, one
18 of these jointly contacted internal electrodes—with formation of a neutral
19 phase—is now not extended to the end of the piezoelectric plies in each case,
20 and the other is extended to the end of the piezoelectric ply in each case.

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22 A contacting with external electrodes is possible in which an insulation layer is
23 applied in simple fashion in the region in which the other internal electrode
24 extended on the non-contacted side to the end lies. The external electrodes can
25 thereby be composed of an electrically conductive screen or net. The form of the
26 external electrode can also be a simple metal strip here, and this can be
27 composed of a conductive material with similar coefficients of thermal expansion
28 as the ceramic material of the piezoelectric plies, e.g., invar.

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30 In another preferred embodiment, however, the external electrodes are
31 advantageously wave electrodes that bridge over the other internal electrode—

1 extended to the end of the piezoelectric ply and not to be contacted—at a
2 specified distance in the shape of a wave.

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4 With the exemplary embodiments named previously, it is therefore possible to
5 extend every other internal electrode to the outside via partial external
6 contacting. With this measure and a partially offset external electrode, e.g., a
7 wave electrode which is connected only in the region of the external contacting
8 and which has a distance of approximately 50 μm , for example, from the internal
9 electrode not to be contacted, a short circuit can be avoided here and the
10 expansion in the external region—by the reduction of the neutral phase—can be
11 increased markedly overall, so that the risk of crack formation is reduced.

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13 It is furthermore advantageous when the multilayer structure of the piezoelectric
14 plies is provided with an electrically insulating ceramic plate on each end of the
15 folded layers.

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17 These and further features of preferred further developments of the invention
18 also arise from the description and the diagrams in addition to the claims, and
19 each of the individual features can be realized on its own or in plurality in the
20 form of sub-combinations in the exemplary embodiment of the invention and in
21 other fields, and can represent advantageous and patentable embodiments in
22 themselves, for which protection is claimed here.

23 *Brief Description of the Drawings*
24 *Diagram*

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26 Exemplary embodiments of the piezoelectric actuator according to the invention
27 are explained using the diagram.

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29 Figure 1 shows a sectional view through a piezoelectric actuator with a multilayer
30 structure of plies composed of piezoelectric ceramic and having contacted

1 internal electrodes in alternate directions and external electrodes designed in the
2 shape of a wave;
3 Figure 2 shows a side view along the line A-A of Figure 1, and
4 Figure 3 shows a partial sectional view of an exemplary embodiment having
5 insulated regions in the region of each non-contacted internal electrode extended
6 toward the outside.

7 *Preferred*

8 Description of the ~~Exemplary~~ Embodiments
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10 A piezoelectric actuator 1 is shown in Figure 1 that is constructed in a fashion
11 known per se out of piezoelectric films 2 of a quartz material having a suitable
12 crystal structure, so that, by utilizing the "piezoelectric effect" when applying an
13 external electrical voltage to internal electrodes 3 and 4 as well as 5 and 6, etc.
14 by way of external electrodes 7 and 8 contacted externally, a mechanical
15 reaction of the piezoelectric actuator 1 takes place.

16
17 It is furthermore obvious in Figure 1 that the external electrodes are designed as
18 wave electrodes 7 and 8 that are always contacted at contact surfaces 9 and 10
19 with two internal electrodes having the same polarity. Every other internal
20 electrode 3, 5 or 4, 6 having the same polarity in each case is continuous to the
21 other end of the piezoelectric actuator 1 and is hereby insulated from this by
22 means of a wave 11 of the respective external electrode 7 and 8 not to be
23 contacted.

24
25 One electrically insulating head plate 12 and one foot plate 13 each are also
26 applied to the external piezoelectric plies of the films 2, by means of which the
27 entire piezoelectric actuator 1 can be insulated toward the outside.

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29 To illustrate the exemplary embodiment according to Figure 1, a side view along
30 A-A from Figure 1 is shown in Figure 2, in which a top view of the external

1 electrode 8 can be seen. The same components are labelled with the identical
2 reference numerals here.

3

4 A second exemplary embodiment of a piezoelectric actuator 1 having another
5 external contacting 16 is shown in Figure 3. A simple metal foil 14 is available
6 here as the external electrode, which touches an insulation layer 15 applied in-
7 between in the region of the internal electrodes 5, etc. not to be contacted. The
8 same effect can therefore be achieved as in the exemplary embodiment
9 according to Figures 1 and 2.

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